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STUDIES IN PALEOPATHOLOGY.

III. OPISTHOTONUS AND ALLIED PHENOMENA AMONG FOSSIL VERTEBRATES

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EVERY student of the fossil vertebrates who is fortunate enough to collect a number of complete or approximately complete skeletons of fossil vertebrates is almost sure to be impressed with the frequency of the peculiar curve to the backwardly bent neck and the rigid appearance of the limbs, if these members are preserved in anything like the position assumed by the animal at death. This attitude of the skeleton is very common in the petrified remains of extinct animals and it is doubtless what is known to medical men as opisthotonos. Williston[1] in describing the remains of *Cimoliosaurus Snowii,* a long-necked plesiosaur, from the Cretaceous of Kansas, says:

> The specimen comprises the skull and twenty-eight cervical vertebræ, all attached and with their relative positions but little disturbed. They lie upon the right side, with the usual opisthotonic curve to the neck, and are all laterally compressed.

The attitude has been noted among many other fossil vertebrates, but its significance, so far as I am aware, has never been commented upon.

Many of the beautifully complete skeletons of the small pterodactyls (Fig. 1), *Pterodactylus longirostris, P. brevirostris, P. elegans,* from the lithographic slate of Aichstädt, which were described many years ago by Goldfuss, Cuvier, Wagner and Soemmering, exhibit a marked opisthotonic curve to the neck and a more rigid appearance to the skeleton as a whole than is common among the skeletons of these remarkable vertebrates. *Pterodactylus*

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[1] *Trans. Kansas Acad. Sci.,* 1890, p. 1.

longirostris Cuvier has the jaw gaping as if trismus was not an accompaniment of opisthotonos, such as is usually the case in recent times, or else the jaw was secondarily moved by the action of the water after the dissolution of the muscles. Other pterodactyls, such as *Pterodactylus scolopaciceps, P. longicollum,* and others described by Plieninger[2] from the Jura of Swabia show no indication of any spastic distress.

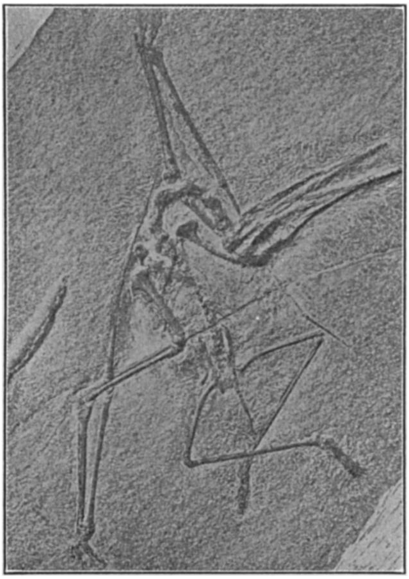

FIG. 1. ***Pterodactylus micronyx*** **H. v. Meyer from the lithographic slates of Eichstädt in Bavaria. The original is in the paleontological collections at Munich. This specimen shows a typical opisthotonic position. One half natural size. After Broili.**

The toothed bird (Fig. 2), *Archeopteryx macroura,* from the lithographic slates, commonly figured in the textbooks of geology, zoology, and paleontology, exhibits a pronounced opisthotonos, which may be slightly exaggerated in all the slender-necked vertebrates having a relatively heavy head. The weight of the head may have added to the curve, but the position is none the less a genuine opisthotonos. The skeleton of a small dinosaur,

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[2] *Paleontographica,* Bd. LIII, pp. 210–313, 6 Tafeln, 1907.

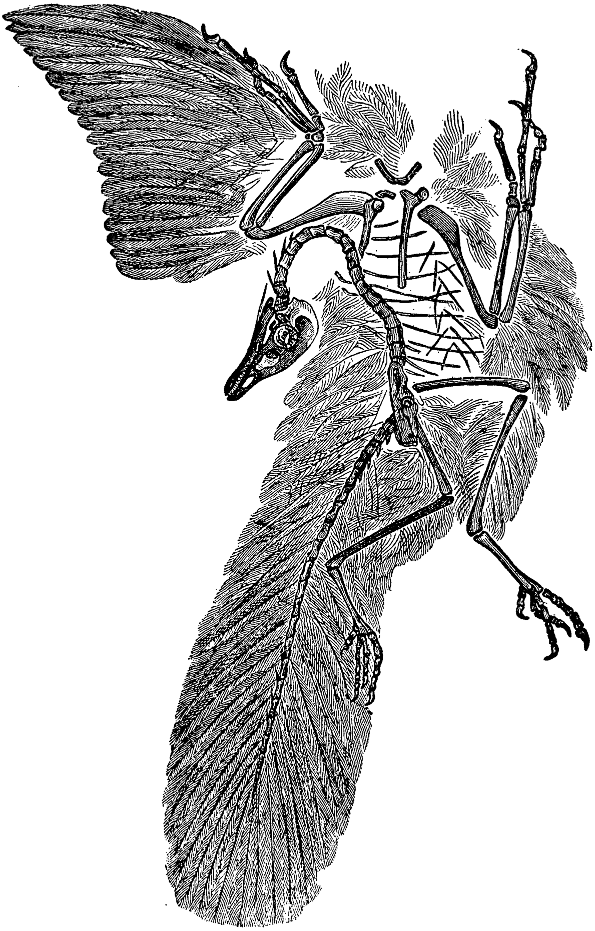

FIG. 2. *Archaeopteryx macroura* from the lithographic slates, showing a typical opisthotonos. × ¼.

about the size of the modern turkey, described and figured by Hoernes as *Compsognathus longipes* Wagn. (Fig. 3) from the lithographic slate of Kelheim, exhibits an unusually well-developed opisthotonos, the skull lying far back over the pelvis.

Probably the most complete representation of opisthotonos among fossil vertebrates is that seen in the skeleton of the small cursorial dinosaur, *Struthiomimus altus*

(Fig. 4) described by Osborn[3] from the Belly River series. The skeleton of this interesting dinosaur is mounted in a panel mount where the skeletal parts are placed approximately as found (Fig. 4). The attitude is typically opisthotonos, the jaws exhibiting trismus, with the head thrown sharply back over the sacrum, the tail thrown sharply up; the toes strongly contracted, with the

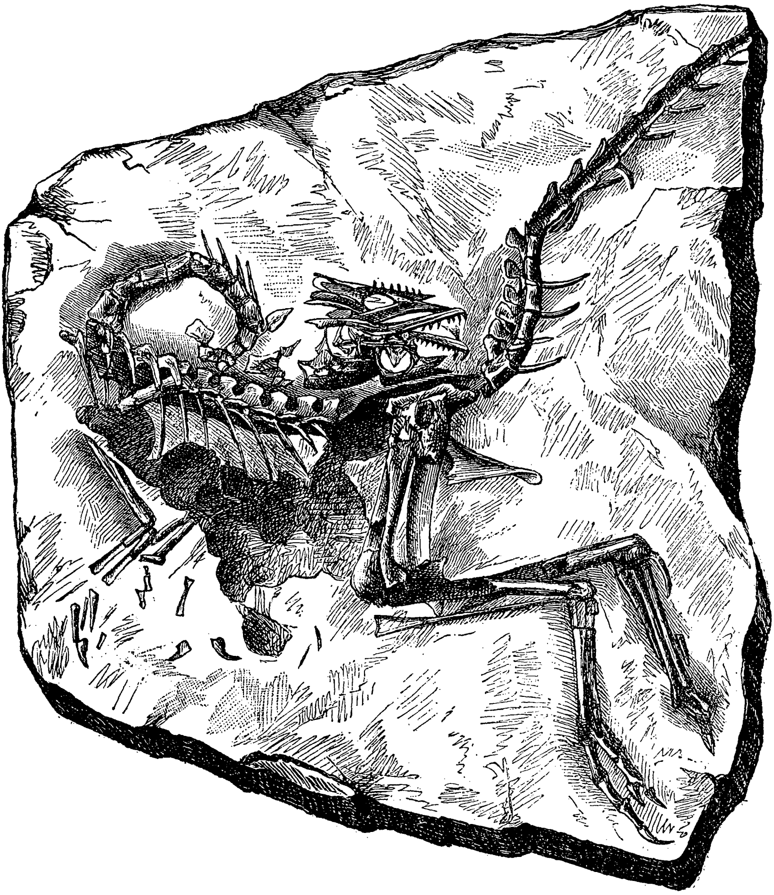

FIG. 3. *Compsognathus longipes* Wagner, from the slates of Kelheim. The position of the head and tail are characteristic expressions of a tetanic spasm. After Hoernes.

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[3] Osborn, H. F., 1917, "Skeletal Adaptations of *Ornitholestes, Struthiomimus, Tyrannosaurus,*" *Bull. of the Amer. Mus. Nat. Hist.,* Vol. 35, pp. 733-771, Pl. XXIV.

phalanges closely appressed. The whole attitude of the body strongly suggests some severe spastic distress. The animal may have been a plant feeder and its death and spastic distress due to feeding on some poisonous plant, such as to-day causes tetanic spasms in animals. It may have suffered death from a severe cerebrospinal infection, but whatever the cause of its death, the attitude of the animal strongly suggests the effect of disease, and in discussing the history of disease among animals the opisthotonic position exhibited by fossil skeletons must be considered as indicating a possible diseased condition.

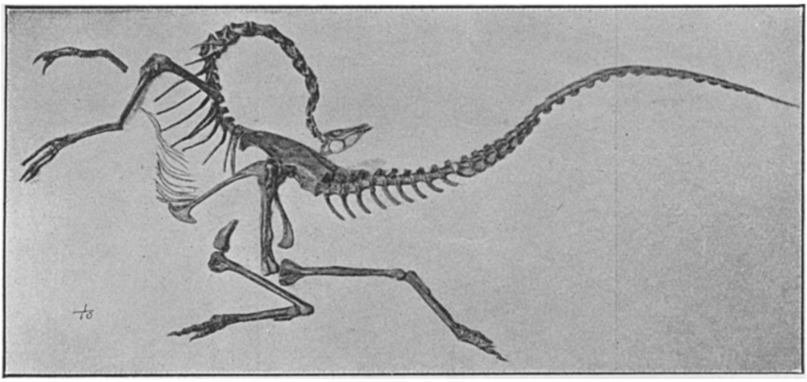

FIG. 4. Skeleton of ***Struthiomimus altus***. Genotype specimen, Amer. Mus. 5339. 1/30 natural size. In this panel mount the animal is placed approximately as found. The attitude is typically opisthotonos. After Osborn.

The correlative phenomenon, pleurothotonos, is less common among the higher vertebrates, but is not uncommon among the fishes. This is evidently the attitude assumed by the skeleton of the plesiosaur, *Plesiosaurus macrocephalus* (Fig. 5), collected by Miss Mary Anning from the Lias of Lyme Regis, England, and figured by William Buckland in his "Bridgewater Treatise."[4] It is improbable that the head of this long-necked plesiosaur could have been turned into its present attitude by a current of water, since a force sufficiently strong to have moved the heavy head to one side would doubtless have disturbed other portions of the body, and there is no evidence of this in the skeleton.

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[4] Vol. II, Pl. 19, Fig. 1, 1837.

The remarkable specimen of *Geosaurus gracilis* H. von Meyer, from the upper Jurassic lithographic slate of Eichstädt, Bavaria, as described and illustrated by von Ammon, shows a clearly marked instance of pleurothotonos. The body, slightly twisted, is bent into a strong, uniform arch toward the left, the animal having been preserved on its belly.

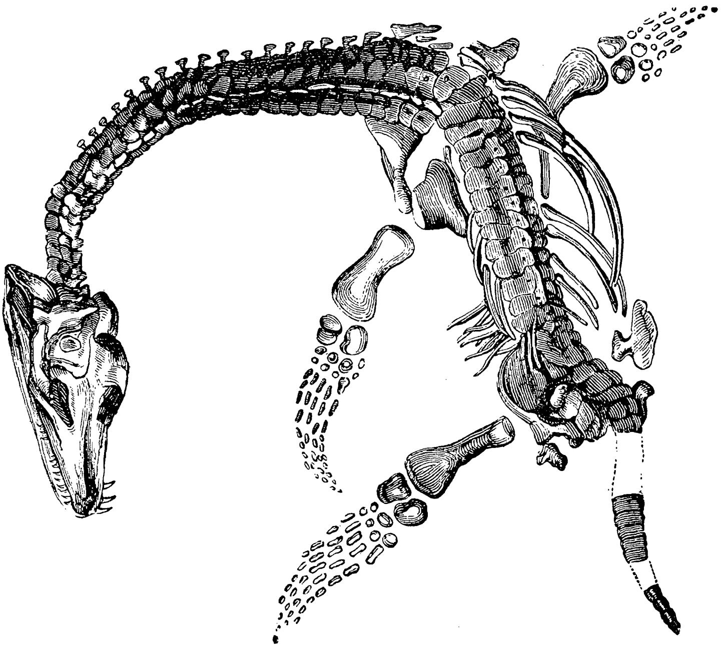

FIG. 5. *Plesiosaurus macrocephalus*, a skeleton from the Lias of England, preserved in a pleurothotonic attitude. After Buckland.

The fishes often assume at death and are fossilized in the pleurothotonic attitude. This is clearly indicated in the fishes from the Solenhofen, *Leptolepis sprattiformis*, as figured by Dreverman, Gaudry and others, though this attitude is also clearly that of fishes attempting to flop out of the soft mud back into the water. It is not a necessary sequence that all laterally compressed vertebrates assume the pleurothotonic attitude, since often the ganoid fishes (Fig. 6), especially, assume the opisthotonos. It is true that the majority of fishes which are preserved in an approximately complete manner exhibit no trace of either of these attitudes. The great series of Triassic fishes from Connecticut seldom exhibit indications of either of these phenomena. A single specimen of *Catopterus gracilis,* of those figured by Eastman,[5] exhibits the opisthotonos, and a single one, *Ptycholepis marshi,* exhibits pleurothotonos. Of the scores of specimens of these fishes described by Newberry and Eastman a very small percentage show any sign of spastic distress.

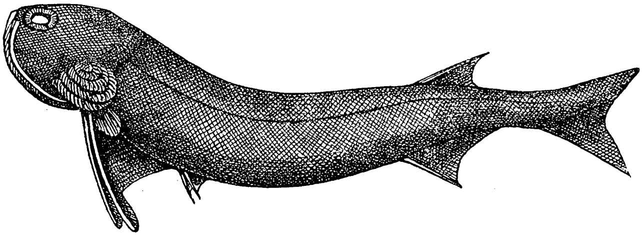

FIG. 6. *Acanthodes gracilis* F. Roemer, a ganoid fish from the Permian of Klein-Neundorf, Lower Silesia, showing an opisthotonic position. After Hoernes. Hoernes.

As a clinical manifestation of great severity, opisthotonos and the correlative phenomena, pleurothotonos and emprosthotonos (episthotonos), have long been well known in human beings as accompanying certain phases of tetanus, abscesses of the brain, otitis media, hysteria, cerebrospinal meningitis, strychnine poisoning, and other afflictions, in which toxins affecting the nervous system are liberated. In these manifestations the muscles of the body, the spine and the extremities are strongly flexed. This characteristic attitude of the spasm has been graphically figured (Fig. 7) by Sir Charles Bell in his "Anatomy of the Expressions," where he says:

> I have here given a sketch of the true Opisthotonos, where it is seen that all the muscles are rigidly contracted, the more powerful flexors

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[5] Bulletin 18, State of Connecticut, State Geol. and Natl. Hist. Survey, Pl. IX.

> prevailing over the extensors. Were the painter to represent every circumstance faithfully, the effect might be too painful, and something must be left to his taste and imagination.

Opisthotonos has also been described by Falls[6] as occurring in the fetus in utero, the cause for which is still unknown.

It is a matter of great interest to find these same manifestations represented in the fossilized skeletons of ancient vertebrates. The majority of the attitudes assumed by the fossils may be due to the spasm usually incident to death, the *Todeskampf* of the Germans, or to accidental shifting after death. Many of the vertebrates whose skeletons are found in anything like a complete state of preservation do not show these manifestations. It is on the whole unusual for fossil vertebrates to show opisthotonos and much more common in the slender-necked species. It is possible that the animals whose skeletons are preserved in the above-mentioned attitudes had suffered death owing to diseases similar to tetanus, cerebrospinal meningitis, or similar disturbances.

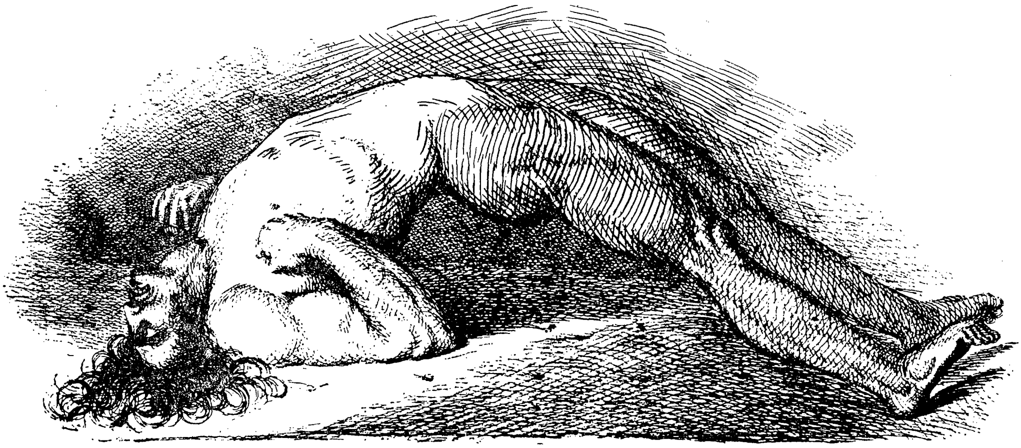

FIG. 7. Charles Bell's drawing of a man in opisthotonos.

The skeleton of *Mesosaurus brasiliensis* from the

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[6] Surgery, Gynecology and Obstetrics, January, 1917, pp. 65–67.

Permian of Brazil[7] exhibits a slight degree of opisthotonos (Fig. 8) such as is common in the death struggle of many modern vertebrates. There can be, I think, little doubt that many of the opisthotonic attitudes assumed by fossil vertebrates are easily explained as a phenomenon accompanying the "Todeskampf," but whether all can be so explained on this basis is extremely doubtful. It is certainly not true that all vertebrates exhibit indications of such spasms. While complete skeletal remains of fossil vertebrates are relatively rare, yet there is a sufficient number preserved which have been described to determine the relative frequency of these positions.

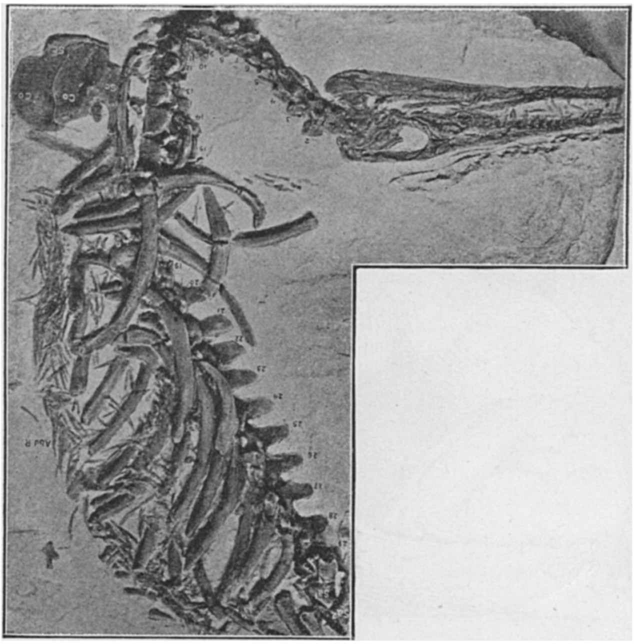

FIG. 8. *Mesosaurus brasiliensis* McGregor from the Permian of Brazil, showing a slight opisthotonos. After McGregor.

In the many complete skeletons of fossil reptiles from the Eocene of France described by L. Lortet[8] only four,

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[7] McGregor, J. H., 1908, "Commissao de Estudos das Mines, etc.," Pl. IV.

[8] L. Lortet, 1892, "Les Reptiles du Bassin du Rhône," Archives du Museum d'Histoire Naturelle de Lyon, Tome V, pp. 3–139, Pl. I–XII.

Alligatorium Meyeri (Pl. X), two specimens of *Alligatorellus Beaumonti* (Pl. XI), and *Crocodileimus robustus* (Pl. IX), exhibit any degree of the opisthotonic attitude. Only one, *Pleurosaurus Goldfussi* (Pl. VII), exhibits the pleurothotonos. The majority of the remaining skeletons figured show no spastic distress whatever. So that while we may say that these two positions are common they are rather the unusual than the usual state of affairs.

On the other hand the dinosaurs *Struthiomimus altus* and *Compsognathus longipes,* many specimens of small pterodactyls and the fossil bird *Archeopteryx* exhibit such a marked opisthotonic attitude as to lead one to infer some cerebral-spinal or other intracranial infection which would have been easily possible in the poorly protected brain case of these early vertebrates. It requires but a glance at the nature of the brain case of the early vertebrates to see how poorly protected the cerebrospinal spaces were. Ingress of infecting bacteria may have been through any of the numerous nerve or vascular foramina, through the thin cancellous walls separating the brain case from the sphenoidal sinus, and through the anterior end of the brain case which was often protected only by a membranous covering, by cartilage, or by very thin bony plates.

The possible presence of the infecting bacteria has been so well established by the investigations of Walcott,[9] van Tieghem and Renault,[10] that little need be said here concerning them. Walcott has described and figured bacteria from fossilized Pre-cambrian algæ of central Montana, supposedly *Micrococcus,* the bacteria being arranged in groupings characteristic of the *Staphylococcus* isolated from a case of Pemphigus neonatorum by Falls, by whose courtesy a photograph has been used for comparison. Renault has described a great variety of bacteria, many of which are apparently similar to the bacteria of to-day.

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[9] Walcott, C. D., 1915, ''Discovery of Algonkian Bacteria,'' *Proc. Natl. Acad. Sci.,* Vol. 1, p. 258, Figs. 2 and 3; 1914, ''Pre-Cambrian Algonkian Algal Flora,'' *Smith. Misc. Coll.,* Vol. 64, No. 2 (Publication 2271).

[10] Renault, B., 1900, ''Microorganismes des combustibles fossiles.'' Bulletin de la Société de l'Industrie minerale Saint-Etienne, Serie III, 1899, Tome 13, pp. 865–1161; 14 (1–2), pp. 5–159, 1900, with Atlas, 1898–1899, Pl. X–XXV, Atlas, 1900–01, Pl. I–V.

In searching for evidences of disease among fossil vertebrates I have been interested in making the above comparisons. In the light of the above study it seems probable that some of the instances of opisthotonos and pleurothotonos among fossil vertebrates may be due to acute cerebrospinal infections, the petrified skeletons exhibiting trismus, rigidity of the limbs, and the peculiar backward curvature of the vertebral column so common to-day as clinical manifestations of spastic distress. This is especially probable in the cases where the skeletons exhibit such marked opisthotonos and pleurothotonos as do many of the specimens above referred to. It may then be said that opisthotonos as seen in the skeletons of fossil vertebrates indicates disease only in those exaggerated cases of spastic distress as is evidenced by the attitudes assumed by fossil vertebrates, such as the small dinosaur, *Struthiomimus altus,* and the bird, *Archæopteryx macroura.* Not all vertebrates preserved in opisthotonus were victims of disease, but many of them suggest a strong neuro-toxic condition.